www.defra.gov.uk

2008 Guidelines to Defra's GHG Conversion Factors:

Methodology Paper for Transport Emission Factors

July 2008

Department for Environment Food and Rural Affairs

Department for Environment, Food and Rural Affairs
Nobel House
17 Smith Square
London SW1P 3JR

Tel: 020 7238 6000
Website: www.defra.gov.uk

Information about this publication is available from:

AEA
The Gemini Building
Fermi Avenue
Harwell
Didcot
OX11 0QR

This document is available on the Defra website and has been produced by AEA

Published by the Department for Environment, Food and Rural Affairs

2008 Guidelines to Defra's GHG Conversion Factors:
Methodology Paper for Transport Emission Factors

Contents

I. Introduction

1. Emissions factors are required to estimate the CO_2 impact per km (or passenger-km, tonne-km) from passenger and freight transport. These factors are to be used in a number of different policies including: offsetting, Defra (and DfT) personal CO_2 calculators and to update the Guidelines to Defra's Greenhouse Gas (GHG) Conversion Factors, which represent the current official set of government emissions factors. This paper outlines the methodology used to update the emissions factors for passenger and freight transport for the 2008 update. The new factors are presented at the end of each of the relevant following sections.

2. Since the previous update, significant work has been carried out to provide a code for offsetting. As part of the requirements of this work, a standard set of emission factors for each of the sources needed to be developed to calculate the emissions. Existing factors have been supplemented by updated/new factors developed for aviation (by seating class), as well as for other passenger transport modes (including buses, vans, taxis and cars by market segment) and for freight transport. This methodology paper explains how the existing factors have been updated and the new factors have been developed.

3. Further information about the current emission factors annexed to the Company Reporting Guidelines (the Defra GHG Conversion Factors) and the factors used in the Act on CO_2 calculator on these can be found at: http://www.defra.gov.uk/environment/business/envrp/conversion-factors.htm, and http://www.defra.gov.uk/environment/climatechange/uk/individual/actonco2/index.htm

4. The factors will be set for the next financial year, 2008/2009. It is the intention to review and update them once a year.

5. **At this stage indirect emissions are not included**, for example those associated with the manufacture of a product or the production and distribution of fuels and the factors do not therefore cover such situations. Work being carried out looking to better understand such emissions may allow expansion to include indirect emissions in the future. Similarly work is also being carried out to include non-CO_2 greenhouse gases.

II. Aviation

Previous Approach

6. The Annexes to the Defra Company Reporting Guidelines (CRG), released in July 2007, reported CO_2 emission factors for estimating greenhouse gas emissions (the Defra GHG Conversion Factors).

7. For **air passenger transport**, there were three factors presented, one for domestic, one for short haul and one for long haul, as follows:
   a. Long haul 105.6 g/CO_2 per passenger km
   b. Short haul 130.4 g/CO_2 per passenger km
   c. Domestic 158.0 g/CO_2 per passenger km

8. These factors were presented together with a methodology paper on the Defra website. An extract from the 2007 methodology paper on the development of these emission factors is presented in the Annex to this paper.

9. The factors are used in the Act on CO_2 calculator released in June 2007 and in the July 2007 release of the Defra GHG conversion factors (DCF). They were based on more up to date information and assumptions than the previous (2005) version, allowing a more representative view of the emissions per passenger km for different types of flights.

10. However, since their release a number of criticisms in the assumptions used in the calculation of the emission factors have been raised by the aviation industry. The main comments include the following:
   a. The load factor used for short-haul flights (65%) was too low;
   b. The short-haul flight calculation should include newer, more efficient aircraft in the calculations (such as Airbus 319 and Boeing 737-800), as these comprise a significant proportion of European flights.

c. Some of the average seating capacities on the different aircraft types were questioned;
d. Freight carried on passenger services has not been taken into account in the calculations. This is particularly significant for long-haul flights.

11. In addition to these issues, there has also been interest in taking into account the seating class in the calculation of emission factors. This is because premium class seating takes up significantly more room on (particularly long-haul) flights, reducing the total passenger seating capacity (and therefore efficiency per passenger transported) compared to an all-economy seating equivalent.

12. For **air freight transport**, there were two factors presented previously (in the 2005 update for the CRG), one for short haul and one for long haul, as follows:
    a. Long haul 0.57 kg/CO_2 per tonne km
    b. Short haul 1.58 kg/CO_2 per tonne km

13. These previous air freight factors were calculated on the basis of freight transport by dedicated cargo services only and did not take into account freight transported on passenger services. As already mentioned this is particularly significant for long-haul services.

14. The following sections summarise the approach taken to revise and expand the currently used emission factors for future use in carbon offsetting, the Act on CO_2 calculator and in the Defra GHG conversion factors. The emission factors for passenger and freight air transport have been calculated in a consistent basis.

New Passenger Air Transport Emission Factors

15. Following feedback received on the emission factors currently used in the Act on CO_2 calculator and DCF[1] datasets and discussions with DfT and the aviation industry we have re-evaluated the assumptions used in calculating average emission factors for flights.

16. The new average factors (presented at the end of this section) have been calculated in the same basic methodology as previously (see Annex), using the aircraft specific fuel consumption/emission factors from AEIG (2006)[2]. A full summary of the expanded representative aircraft selection and the main assumptions influencing the emission factor calculation is presented in Table 1. The principal changes to the calculation methodology, data and assumptions include:
    a. A significantly wider variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights.

[1] Defra GHG conversion factors for the Company Reporting Guidelines, 2007. Also used in the government's 'Act on CO_2' calculator.
[2] EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (2006), available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf

b. Average seating capacities, load factors and proportions of passenger km by the different aircraft types have all been calculated from CAA (Civil Aviation Authority) statistics for UK registered airlines for the year 2006 (the latest available complete dataset);
c. Short-haul flights average load factor changed from 65% to 81%. The revised figure is the average for all European international flights calculated from CAA statistics for the selected aircraft. This figure may be compared to an average of 79.7% for all international flights from DfT Transport Statistics for 2006.
d. Long-haul flights average load factor has changed from 79.7% to 78%. The revised figure is the average for all non-European international flights calculated from CAA statistics for the selected aircraft;
e. Freight transported on passenger services has also been taken into account (with the approach taken summarised in the following section). Accounting for freight makes a significant difference to long-haul emission factors.
f. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

Table 1: Assumptions used in the calculation of revised average CO_2 emission factors for passenger flights

	Average No. Seats	Average Load Factor	Proportion of passenger km
Domestic Flights			
Boeing 737-400	143	59%	22%
Boeing 737-700	151	75%	11%
Airbus A319/A320	157	75%	44%
BAE Jetstream 41	30	45%	4%
BAE 146	102	51%	7%
Dash 8 Q400	78	49%	12%
Total	***135***	***65%***	***100%***
Short-haul Flights			
Boeing 737-400	143	76%	13%
Boeing 737-800	188	83%	12%
Airbus A319/A320	157	79%	44%
Boeing 757	228	86%	30%
Total	***181***	***81%***	***100%***
Long-haul Flights			
Boeing 747-400	349	78%	47%
Boeing 767	254	82%	17%
Boeing 777	235	75%	18%
Airbus A330	330	84%	7%
Airbus A340	290	71%	10%
Total	***304***	***78%***	***100%***

Notes: Figures have been calculated from 2006 CAA statistics for UK registered airlines for the different aircraft types.

Taking Account of Freight

17. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers and their luggage, as well as freight. The CAA data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights. In fact, the quantity of freight carried on scheduled long-haul passenger flights is nearly 5 times higher than the quantity of freight carried

on scheduled long-haul cargo services. The apparent importance of freight movements by passenger services creates a complicating factor in calculating emission factors. Previous emission factor for passenger services have been calculated assuming all the CO_2 is allocated to the passengers. However, given the significance of air freight transport on passenger services there are good arguments for developing a method to divide the CO_2 between passengers and freight.

18. The CAA data provides a split of tonne km for freight and passengers (plus luggage) by airline for both passenger and cargo services. This data may be used as a basis for an allocation methodology. There are essentially three options, with the resulting emission factors presented in Table 2:
    a. ***No Freight Weighting*****:** Assume all the CO_2 is allocated to passengers on these services. ;
    b. ***Freight Weighting Option 1*****:** Use the CAA tonne km (tkm) data directly to apportion the CO_2 between passengers and freight. However, in this case the derived emission factors for freight are significantly higher than those derived for dedicated cargo services using similar aircraft.
    c. ***Freight Weighting Option 2:*** Use the CAA tonne km data modified to treat freight on a more equivalent /consistent basis to dedicated cargo services. This takes into account the additional weight of equipment specific to passenger services (e.g. seats, galleys, etc) in the calculations.

Table 2: CO_2 emission factors for alternative freight allocation options for passenger flights

Freight Weighting:	**None**		**Option 1: Direct**		**Option 2: Equivalent**	
Mode	**Passenger tkm % of total**	**gCO_2 /pkm**	**Passenger tkm % of total**	**gCO_2 /pkm**	**Passenger tkm % of total**	**gCO_2 /pkm**
Domestic flights	100.0%	175.9	99.7%	175.3	99.7%	175.3
Short-haul flights	100.0%	98.9	99.4%	98.3	99.4%	98.3
Long-haul flights	100.0%	125.5	71.2%	89.3	88.1%	110.6

19. The basis of the freight weighting **Option 2** is to take into account of the supplementary equipment (such as seating, galley) and other weight for passenger aircraft compared to dedicated cargo aircraft in the allocation. The Boeing 747 cargo configurations account for the vast majority of long-haul freight services (and over 90% of all tkm for dedicated freight services). In comparing the freight capacities from BA World Cargo's website[3] of the cargo configuration (125 tonnes) compared to passenger configurations (20 tonnes) we may assume that the difference represents the tonne capacity for passenger transport. This 105 tonnes will include the weight of passengers and their luggage (around 100 kg per passenger according to IATA), plus the additional weight of seating, the galley, and other airframe adjustments necessary for passenger service operations. For an average seating capacity of around 350 passengers, this means that the average weight per passenger seat is just over 300 kg. This is around 3 times the weight per passenger and their luggage alone. In the **Option 2** methodology this factor of 3 difference is

[3] British Airways World Cargo provides information on both passenger and dedicated freight services at: http://www.baworldcargo.com/configs/

used to upscale the CAA passenger tonne km data, increasing this as a percentage of the total tonne km – as shown in Table 2.

20. It does not appear that there is a distinction made (other than in purely practical size/bulk terms) in the provision of air freight transport services in terms of whether something is transported by dedicated cargo service or on a passenger service. The related calculation of freight emission factors (discussed in a later section) leads to very similar emission factors for both passenger service freight and dedicated cargo services for domestic and short-haul flights. This is also the case for long-haul flights under freight weighting **Option 2**, whereas under **Option 1** the passenger service factors are substantially higher than those calculated for dedicated cargo services. It therefore seems preferable to treat freight on an equivalent basis by utilising freight weighting **Option 2**.

21. **Option 2** has been selected as the preferred methodology to allocate emissions between passengers and freight for the 2008 update.

'Real-World' Uplift

22. As discussed, the developed emissions factors are based on typical aircraft fuel burn over illustrative trip distances listed in the EMEP/CORINAIR Emissions Inventory Guidebook (EIG 2007)[4]. This information is combined with data from the Civil Aviation Authority (CAA) on average aircraft seating capacity, loading factors, and annual passenger-km and aircraft-km for 2006 (most recent full-year data available). However, the provisional evidence to date suggests an uplift in the region of 10-12% to climb/cruise/descent factors derived by the CORINAIR approach is appropriate in order to ensure consistency with estimated UK aviation emissions as reported in line with the UN Framework on Climate Change (UNFCCC), covering UK domestic flights and departing international flights.

23. The emissions reported under UNFCCC are based on bunker fuel consumption and are closely related to fuel on departing flights. The 10% uplift is therefore based on comparisons of national aviation fuel consumption from this reported inventory, with detailed bottom up calculations in DfT modelling along with the similar NAEI approach, which both use detailed UK activity data (by aircraft and route) from CAA, and the CORINAIR fuel consumption approach. Therefore for this version of the Defra CO_2 emission factors an uplift of 10% is included in the emission factors in all the presented tables, based on provisional evidence.

24. The CORINAIR uplift is separate to the assumption that Great Circle Distances (GCD) used in the calculation of emissions should be increased by 9% to allow for sub-optimal routeing and stacking at airports during periods of heavy congestion. This GCD uplift factor is NOT included in the presented emission factors, and must be applied to the Great Circle Distances when calculating emissions.

[4] Available at the EEA website at: *http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851vs2.4.pdf* and *http://reports.eea.europa.eu/EMEPCORINAIR5/en/B851_annex.zip*

25. It should be noted that work will continue to determine a more robust reconciliation and this will be accounted for in future versions of these factors.

26. The revised average emission factors for aviation are presented in Table 3. The figures in Table 3 include the uplift of 10% to correct underestimation of emissions by the CORINAIR methodology (discussed above) and DO NOT include the 9% uplift for Great Circle distance, which needs to be applied separately (and is discussed separately later).

Table 3: Revised average CO_2 emission factors for passenger flights

Mode	Previous factors from 2007		Revised factors for 2008	
	Load Factor%	**gCO_2/pkm**	**Load Factor%**	**gCO_2/pkm**
Domestic flights	65.0%	158.0	66.3%	175.3
Short-haul flights	65.0%	130.4	81.2%	98.3
Long-haul flights	79.7%	105.6	78.1%	110.6

Seating Class Factors

27. The efficiency of aviation per passenger km is influenced by not only the technical performance of the aircraft fleet, but also by the occupancy/load factor of the flight. Different airlines provide different seating configurations that change the total number of seats available on similar aircraft. Premium priced seating, such as in First and Business class, takes up considerably more room in the aircraft than economy seating and therefore reduces the total number of passengers that can be carried. This in turn raises the average CO_2 emissions per passenger km.

28. At the moment there is no agreed data/methodology for establishing suitable scaling factors representative of average flights. However, a review was carried out of the seating configurations from a selection of 16 major airlines[5] and average seating configuration information from Boeing and Airbus websites. 24 different aircraft variants were considered including those from the Boeing 737, 747, 757, 767 and 777 families, and the Airbus A319/320, A330 and A340 families. These represent a mix of the major representative short-, medium- and long- haul aircraft types. The different seating classes were assessed on the basis of the space occupied relative to an economy class seat for each of the airline and aircraft configurations. This evaluation was used to form a basis for the seating class based emission factors provided in Table 4. Information on the seating configurations including seating numbers, pitch, width and seating plans were obtained either directly from the airline websites or from specialist websites that had already collated such information for most of the major airlines (e.g. SeatGuru[6], UK-AIR.NET[7], FlightComparison[8] and SeatMaestro[9]).

[5] The list of airline seating configurations was selected on the basis of total number of passenger km from CAA statistics, supplemented by additional non-UK national carriers from some of the most frequently visited countries according to the UK's International Passenger Survey. The list of airlines used in the analysis included: BA, Virgin Atlantic, Continental Airlines, Air France, Cathay Pacific, Gulf Air, Singapore Airlines, Emirates, Lufthansa, Iberia, Thai Airways, Air New Zealand, Air India, American Airlines, Air Canada, and United Airlines.
[6] See: http://www.seatguru.com/
[7] See: http://www.uk-air.net/seatplan.htm
[8] *See: http://www.flightcomparison.co.uk/flightcomparison/home/legroom.aspx*
[9] *See: http://www.seatmaestro.com/airlines.html*

29. For long-haul flights, the relative space taken up by premium seats can vary by a significant degree between airlines and aircraft types. The variation is at its most extreme for First class seats, which can account for from 3 to over 6 times[10] the space taken up by the basic economy seating. Table 4 shows the seating class based emission factors, together with the assumptions made in their calculation. An indication is also provided of the typical proportion of the total seats that the different classes represent in short- and long-haul flights. The effect of the scaling is to lower the economy seating emission factor in relation to the average, and increase the business and first class factors.

Table 4: Seating class based CO_2 emission factors for passenger flights

Flight type	Size	Load Factor%	gCO_2 /pkm	Number of economy seats	% of average gCO_2/pkm	% Total seats
Domestic	**Average**	**65.3%**	**175.3**	**1.00**	**100%**	**100%**
Short-haul	**Average**	**81.2%**	**98.3**	**1.05**	**100%**	**100%**
	Economy class	81.2%	93.7	1.00	95%	90%
	First/Business class	81.2%	140.5	1.50	143%	10%
Long-haul	**Average**	**78.1%**	**110.6**	**1.37**	**100%**	**100%**
	Economy class	78.1%	80.7	1.00	73%	80%
	Economy+ class	78.1%	129.1	1.60	117%	5%
	Business class	78.1%	234.0	2.90	212%	10%
	First class	78.1%	322.8	4.00	292%	5%

New Freight Air Transport Emission Factors

30. Freight, including mail, are transported by two types of aircraft – dedicated cargo aircraft which carry freight only, and passenger aircraft which carry both passengers and their luggage, as well as freight.

31. Data on freight movements by type of service are available from the Civil Aviation Authority (CAA, 2007). This data show that almost all freight carried by passenger aircraft is done on scheduled long-haul flights and accounts for over 70% of all long-haul air freight transport. How this freight carried on long-haul passenger services is treated has a significant effect on the average emission factor for all freight services.

32. The next section describes the calculation of emission factors for freight carried by cargo aircraft **only** and then the following sections examine the impact of freight carried by passenger services and the overall average for all air freight services.

Emission Factors for Dedicated Air Cargo Services

33. Following the further development of emission factors for passenger flights and discussions with DfT and the aviation industry, revised average emission factors for dedicated air cargo have been developed - presented in Table 5. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied to the CORINAIR based factors.

[10] For the first class sleeper seats/beds frequently used in long-haul flights.

Table 5: Revised average CO_2 emission factors for dedicated cargo flights

Mode	Previous factors from 2005 kgCO_2/tkm	Revised factors for 2008	
		Load Factor%	kgCO_2/tkm
Domestic flights	1.58	56.4%	1.85
Short-haul flights		59.2%	1.32
Long-haul flights	0.57	65.4%	0.60

34. The new factors have been calculated in the same basic methodology as for the passenger flights, using the aircraft specific fuel consumption/emission factors from AEIG (2006)[11]. A full summary of the representative aircraft selection and the main assumptions influencing the emission factor calculation are presented in Table 6. The principal changes to the calculation methodology, data and assumptions include:
    a. A separate factor has been produced for domestic flights;
    b. A significantly wider variety of representative aircraft have been used to calculate emission factors for domestic, short- and long-haul flights;
    c. Average freight capacities, load factors and proportions of tonne km by the different airlines/aircraft types have been calculated from CAA (Civil Aviation Authority) statistics for UK registered airlines for the year 2006 (the latest available complete dataset).
    d. An uplift of 10% to correct underestimation of emissions by the CORINAIR methodology compared to real-world fuel consumption.

Table 6: Assumptions used in the calculation of revised average CO_2 emission factors for dedicated cargo flights

	Average Cargo Capacity, tonnes	Average Load Factor	Proportion of tonne km
Domestic Flights			
Boeing 737-300	16.0	59%	59.9%
Boeing 757-200	27.6	59%	11.7%
BAE ATP	6.0	51%	2.2%
Lockheed L188	12.0	51%	9.3%
BAE 748	6.0	47%	2.5%
BAE 146-200/QT	10.0	51%	14.4%
Total	***15.6***	***56%***	***100.0%***
Short-haul Flights			
Boeing 737-300	16.0	59%	0.5%
Boeing 757-200	27.6	60%	83.7%
BAE ATP	6.0	47%	2.3%
Lockheed L188	12.0	52%	8.7%
Boeing 747-200F	114.2	66%	4.8%
Total	***29.9***	***59%***	***100.0%***
Long-haul Flights			
Boeing 747-400F	125.0	65%	60.1%
Boeing 747-200F	114.2	66%	18.7%
Boeing 757-200	25.8	65%	21.3%
Total	***101.9***	***65%***	***100.0%***

Notes: Figures have been calculated from 2006 CAA statistics for UK registered airlines for the different aircraft types.

[11] EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (2006) – available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf

Emission Factors for Freight on Passenger Services

35. The CAA data provides a similar breakdown for freight on passenger services as it does for cargo services. As already discussed earlier, the statistics give tonne-km data for passengers and for freight. This information has been used in combination with the assumptions for the earlier calculation of passenger emission factors to calculate the respective total emission factor for freight carried on passenger services. These emission factors are presented in the following Table 7 with the two different allocation options for long-haul services.

Table 7: Air freight CO_2 emission factors for alternative freight allocation options for passenger flights

Freight Weighting:	% Total Freight tkm		Option 1: Direct		Option 2: Equivalent	
Mode	Passenger Services (PS)	Cargo Services	PS Freight tkm, % total	Overall $kgCO_2$ /tkm	PS Freight tkm, % total	Overall $kgCO_2$ /tkm
Domestic flights	7.0%	93.0%	0.3%	1.90	0.3%	1.90
Short-haul flights	18.6%	81.4%	0.6%	1.32	0.6%	1.32
Long-haul flights	71.9%	28.1%	28.8%	1.48	11.9%	0.61

36. It is useful to compare the emission factors calculated for freight carried on passenger services (in Table 7) with the equivalent factors for freight carried on dedicated cargo services (in Table 5). The comparison shows that in the case of domestic and European services, the CO_2 emitted per tonne-km of either cargo or combined cargo and passengers are very similar. In other words, freight transported on a passenger aircraft could be said to result in similar carbon dioxide emissions as if the same freight was carried on a cargo aircraft. In the case of other international flights, the factor in Table 7 is more than twice the comparable figure given in Table 5 for **Option 1**, but is the same as the figure for **Option 2**. This would mean that under **Option 1**, freight transported on a passenger aircraft could be said to result in over two times as much CO_2 being emitted than if the same freight was carried on a cargo aircraft. This is counter-intuitive since freight carriage on long-haul services is used to help maximise the overall efficiency of the service. Furthermore, CAA statistics do include excess passenger baggage in the 'freight' category, which would under **Option 1** also result in a degree of under-allocation to passengers. **Option 2** therefore appears to provide the more reasonable means of allocation.

37. **Option 2** has been selected as the preferred methodology for freight allocation for the 2008 update and is included in all the presented emission factors.

Average Emission Factors for All Air Freight Services

38. The following Table 8 presents the final average air freight emission factors for all air freight for the 2008 update. The emission factors have been calculated from the individual factors for freight carried on passenger and dedicated freight services, weighted according to their respective proportion of the total air freight tonne km. Consistent with the passenger aircraft methodology (discussed earlier), a 10% correction factor uplift is also applied

to the CORINAIR based factors. The figures DO NOT include the 9% uplift for Great Circle distances, which needs to be applied separately (and is discussed separately later).

Table 8: Final average CO_2 emission factors for all air freight for 2008 update

	% Total Air Freight tkm		All Air Freight
Mode	**Passenger Services**	**Cargo Services**	**$kgCO_2/tkm$**
Domestic flights	7.0%	93.0%	1.90
Short-haul flights	18.6%	81.4%	1.32
Long-haul flights	71.9%	28.1%	0.61

Other Factors for the Calculation of CO_2 Emissions

Great Circle Fight Distances

39. We wish to see standardisation in the way that emissions from flights are calculated in terms of the distance travelled and any uplift factors applied to account for circling and delay. However, we acknowledge that a number of methods are currently used.

40. A 9% uplift factor is used in the Act on CO_2 calculator and in the UK Greenhouse Gas Inventory to scale up Great Circle distances (GCD) for flights between airports to take into account indirect flight paths and delays, etc. This factor (also provided previously with the Defra GHG conversion factors) comes from the IPCC Aviation and the global Atmosphere 8.2.2.3, which states that 9-10% should be added to take into account non-direct routes (i.e. not along the straight line great circle distances between destinations) and delays/circling.

41. Currently the Act on CO_2 calculator only captures the number of flights taken and assumes average distance factors (plus the 9% uplift) for domestic, short-haul or long-haul flights. It is Defra's intention to incorporate within a future version of the Act on CO_2 calculator the option to perform a calculation based on airport origin and destinations for passenger flights. This would allow a more precise calculation of CO_2 emissions using the Great Circle distances and the above uplift factor specific to the flight details entered.

42. It is not practical to provide a database of origin and destination airports to calculate flight distances. However, the principal of adding a factor of 9% to distances calculated on a Great Circle is recommended (for consistency with the existing Defra/DfT approach) to take into account of indirect flight paths and delays/congestion/circling.

Radiative Forcing

43. The emission factors provided in the 2008 update to Defra's Greenhouse Gas Conversion Factors (DCF) refer to aviation's carbon dioxide emissions only. There is currently uncertainty over the non-CO_2 climate change effects of aviation (including water vapour, contrails, NOx etc) which have been indicatively been accounted for by applying a multiplier in some cases.

44. Currently there is no suitable climate metric to express the relationship between emissions and climate warming effects from aviation but this is an active area of research. Nonetheless, it is clear that aviation imposes other effects on the climate which are greater than that implied from simply considering its CO_2 emissions alone.

45. The application of a 'multiplier' to take account of non-CO_2 effects is a possible way of illustratively taking account of the full climate impact of aviation. A multiplier is not a straight forward instrument. In particular it implies that other emissions and effects are directly linked to production of CO_2, which is not the case. Nor does it reflect accurately the different relative contribution of emissions to climate change over time, or reflect the potential trade-offs between the warming and cooling effects of different emissions.

46. On the other hand, consideration of the non-CO_2 climate change effects of aviation can be important in some cases, and there is currently no better way of taking these effects into account. A multiplier of 1.9 is recommended as a central estimate, based on the best available scientific evidence[12]. If used, this factor would be applied to the emissions factors set out here.

III. Passenger Surface Transport

47. The previous emission factors available in the Defra GHG Conversion Factors and Act on CO_2 calculator covered most of the needs of current off-setting schemes suitably, although there were a number of gaps identified. The following new emission factors were developed to fill these gaps:
    a. LPG/CNG cars and vans;
    b. Car market class based emission factors;
    c. Regular taxis and London Black Cabs.
    d. Petrol and diesel vans;
    e. Separate emission factors for local buses and long-distance coaches;
    f. Large RoPax ferries (carrying passengers and vehicles).

48. The existing emission factors for cars and rail vehicles have also been revisited and in most cases updated to be consistent with more recent data.

Passenger Cars

Emission Factors by Passenger Car Engine Size

49. The Annexes to the Defra Company Reporting Guidelines (CRG)[13], released in July 2005, reported the figures presented in Table 9 below. The factors derived refer to CO_2 emissions per km and are derived from speed emission curves also used by the UK's National Atmospheric Emissions Inventory

[12] Aviation radiative forcing in 2000: An update on IPCC (1999) Meteorologische Zeitschrift 14: 555-561
[13] The annexes updated in 2007 and 2008 are now referred to as the 'Guidelines to Defra's GHG Conversion Factors'.

(NAEI) / Greenhouse Gas Inventory (GHGI). These curves were developed mainly for Air Quality and national Greenhouse Gas emissions inventory purposes and were developed from a dataset derived from actual testing of a selection of different sized and different Euro 3 emission class cars for several different "real world" drive cycles.

Table 9: CO_2 emission factors for cars from the 2005 Defra CRG Annex 6 (July 2005)

Vehicle Type	Engine size	Size label	gCO_2 per km	MPG
Petrol car	< 1.4 l	Small	159.2	40.8
	1.4 - 2.0 l	Medium	188.0	34.6
	> 2.0 l	Large	219.7	29.6
Average petrol car			**178.2**	**36.5**
Diesel car		*Small*	*N/A*	*N/A*
	< 2.0 l	Medium	163.6	45.4
	> 2.0 l	Large	192.6	38.6
Average diesel car			**169.6**	**43.8**

50. These factors took account of the impact of different UK average driving speeds and cycles relative to those of the NEDC (New European Driving Cycle – used in vehicle type approval) and to an extent the impacts of vehicle age. However, they took no account of further 'real-world' effects, such as use of accessories (air con, lights, heaters etc), vehicle payload (only driver +25kg is considered in tests, no passengers or further luggage), poor maintenance (tyre under inflation, maladjusted tracking, etc), gradients (tests effectively assume a level road), weather, more aggressive/harsher driving style, etc.

51. These factors had not been updated to take into account changes to the UK car fleet resulting from new sales and registrations. They also did not provide factors for small diesel cars, which are now a significant part of new car sales, and for hybrid vehicles. Furthermore, they only in part took into account important 'real-world' effects that act to significantly increase fuel consumption over test-cycle based figures. In 2007, several alternative datasets were considered in looking to update the car CO_2 factors to better reflect the current fleet and real-world conditions.

52. In terms of uplifting NEDC based emission factors to 'real-world' values, there are a number of sources of evidence and information to inform a decision on an appropriate value. Results of recent research by TUEV Nord for the German Environmental Agency[14] have shown that the CO_2 emissions for the NEDC test cycle can vary up to +30% for a specific vehicle type, due to vehicle and driving behaviour variations. The study concludes that on average the CO_2 emissions in real traffic are systematically higher than indicated by the type approval results by a factor in the order of +10-15%. In comparison, the IEA (International Energy Agency) uses a factor of +15-18% in its model

[14] Investigations for an Amendment of the EU Directive 93/116/EC (Measurement of Fuel Consumption and CO_2 Emission). Study by TUEV Nord Mobilitaet GmbH & Co.KG, Institute for Vehicle Technology and Mobility. Carried out by order of the German Environmental Agency (UBA). November 2005.

calculations to convert from test-cycle to 'real-world' values. This is also similar to the value of +15.5% quoted by Energy Saving Trust (EST) based on information from ARVAL (the UK's biggest fleet operator) on observations from the real performance of its vehicles relative to test cycle data. The ARVAL factor provides the only information specific to the UK, although it may be a small over-estimate for private cars in some cases due to the nature of fleet vehicle usage compared to more typical driving styles of the general public.

53. Other information from EST on the impacts of various real-world effects on fuel consumption also provides support for the application of uplift factors. These effects include general maintenance and tyre pressure (increase of 1% for every 3 PSI under pressure), eco-driving (up to 5-10% reduction), air conditioning use (increase of 5% for average mixed use; up to 20-25% increase when on full power[15]).]

54. Air conditioning (a/c) is a particularly significant component of 'real-world' impacts on fuel consumption, as it is not currently included in the type-approval testing procedures. It is estimated that today around 85% of new cars are sold with air conditioning systems fitted as standard[16], with nearly all medium and large cars have air conditioning as standard equipment[17]. SMMT (Society for Motor Manufacturers and Traders) has estimated that the proportion of the car fleet with a/c units increased from 10% in 1993 to 55% by 2002 further to 70% by 2005[18].

55. An uplift factor of **+15% over NEDC based gCO_2/km** factors was agreed with DfT in 2007 to take into account the combined 'real-world' effects on fuel consumption not already taken into account in the previous factors. [Note: This represents a decrease in MPG (miles per gallon) over NEDC figures of about 13% for petrol cars and 9% for diesel cars]. This factor may be updated/revised in future years should better information become available.

56. Several datasets were identified to help inform the updating of the average CO_2 emission factors in 2007. The most relevant one identified was based on SMMT data. This data provided a numbers of registrations and averages of the NEDC gCO_2/km figures for new vehicles registered between 1997 and 2005[19]. For the 2008 update an expanded dataset has been obtained to also include data for 2006 and 2007, and is presented in Table 10. This dataset represents a good indication of the actual UK fleet split of vehicle/engine sizes and relative NEDC gCO_2/km by size category. The existing engine size categories provide a reasonable spread across the registrations. It therefore appears to provide validation for the split (and the new 'small' diesel category).

[15] Source: tests carried out by ADEME, France.
[16] From: www.boschautoparts.co.uk/teACon1.asp?c=2&d=2
[17] From: www.eberspacher.com/aircon.php?section=products
[18] From CfIT (Commission for Integrated Transport): www.cfit.gov.uk/plenaries/0501mfp3.htm
[19] The SMMT gCO_2/km dataset for 1997 represented around 70% of total registrations, which rose to about 99% by 2000 and essentially all vehicles thereafter.

Table 10: Average CO_2 emission factors and total registrations from SMMT data for 1997 to 2007 (provided by EST, based on data sourced from SMMT).

Vehicle Type	Engine size	Size label	gCO_2 per km	MPG	Total no. of registrations	% Total
Petrol car	< 1.4 l	Small	152.7	42.8	8,417,053	43%
	1.4 - 2.0 l	Medium	188.6	34.7	9,312,278	48%
	> 2.0 l	Large	260.9	25.1	1,765,218	9%
Average petrol car			**179.6**	**36.4**	**19,494,549**	**100%**
Diesel car	<1.7 l	Small	127.4	58.3	1,047,622	16%
	1.7 - 2.0 l	Medium	158.4	46.9	4,120,506	62%
	> 2.0 l	Large	217.3	34.2	1,486,308	22%
Average diesel car			**166.7**	**44.6**	**6,654,436**	**100%**

57. The 2005 conversion factors for small and medium sized petrol and diesel cars appeared approximately consistent with the original 1997-2005 dataset – being in general slightly higher, as would be expected for the UK fleet average. However, the 'large' category emission factors for both petrol and diesel in the 2005 guidelines appeared to be significantly low and in need of revising upwards. The reason for this discrepancy is likely to be two-fold: Primarily it is probably due to the selection of test vehicles that formed the basis behind the original speed-emission curves used to derive the old factors. These vehicles covered typical family cars and did not cover the very large (e.g. 4x4 or SUV) or higher-performance cars (e.g. sports, executive and luxury)[20]. A secondary factor is that the proportion of larger and higher performance categories has increased in recent years (particularly for diesel-powered cars), increasing the average for cars falling in the 'large' engine size category.

58. The SMMT dataset was therefore used to calibrate the existing Defra conversion factors (DCF) to produce more up-to-date and accurate emission factors by size category based on NEDC for the 2007 update. The update data including 2006 and 2007 information was used to further refine these factors. The *New 'Real-World'* Defra conversion factors for 2008, presented in Table 11, include the +15% uplift factor to take into account the 'real-world' impacts on fuel consumption not captured by drive cycles such as the NEDC in type-approval. The overall average figures have been calculated from a mileage weighted average of the petrol and diesel averages, using data provided by DfT[21] on the relative % total mileage by petrol and diesel cars for 2006. This split in total annual mileage was 68.9% petrol and 31.1% diesel, and can be compared to the respective total registrations of the different vehicle types for 1997-2007, which was 74.6% petrol and 25.4% diesel.

59. New CO_2 emission factors were also generated for medium and large hybrid petrol-electric cars for the 2007 update. These are based on average emission factors for the main models currently widely available on the UK

[20] The focus of the work was also primarily towards development of air quality pollutant emission factors, where emission standards are very similar or the same across car sizes.
[21] Analysis of annual mileage by vehicle type 2002/2006 provided DfT ITEA Division, 31 March 2008.

market and are unchanged for the 2008 update. For medium cars this is an average of figures for the Toyota Prius and Honda Civic IMA. For large cars the emission factor is an average of data for the Lexus GS450h and Lexus RX400h.

60. Individuals may wish to calculate their carbon emissions for a particular door-to-door journey using Transport Direct[22] - www.transportdirect.info.

Table 11: Revised CO_2 emission factors for cars for 2008 update

Vehicle Type	Engine size	Size label	Final 2008 New 'real-world' DCF [(1)]	
			gCO_2 per km	**MPG**
Petrol car	< 1.4 l	Small	180.9	36.2
	1.4 - 2.0 l	Medium	213.9	30.6
	> 2.0 l	Large	295.8	22.1
Average petrol car			**207.0**	**31.6**
Diesel car	<1.7 l	Small	151.3	49.1
	1.7 - 2.0 l	Medium	188.1	39.5
	> 2.0 l	Large	258.0	28.8
Average diesel car			**197.9**	**37.5**
Hybrid petrol-electric car	(2)	Medium	126.2	51.5
	(3)	Large	224.0	29.0
Average car (unknown fuel)	(3)	-	**204.2**	**32.9**

Notes:
(1) Using a +15% uplift factor for NEDC ⇒ 'real-world';
(2) Average of Toyota Prius and Honda Civic IMA; (3) Average of Lexus GS450h and RX400h.
(4) Estimated from the relative vkm data from DfT for petrol (68.9%) and diesel (31.1%)

LPG and CNG Passenger Cars

61. According to the Energy Savings Trust (EST[23]), LPG and CNG cars results in 10-15% reduction in CO_2 relative to petrol cars, similar to diesel vehicles. New factors for LPG and CNG cars, presented in Table 12, were calculated based on an average 12.5% reduction in CO_2 emissions relative to the emission factors for petrol cars from the Defra conversion factors dataset. Due to the significant size and weight of the LPG and CNG fuel tanks it is assumed only medium and large sized vehicles will be available.

Table 12: New emission factors for LPG and CNG passenger cars

Car fuel	Car size	gCO_2 per km
LPG or CNG	Medium	189.2
	Large	259.4
	Average	**224.3**

[22] Note that the emission factors and vehicle size categorisation in Transport Direct are not identical to the Defra conversion factors, as they are used in a different way and for a different purpose. However both figures produce consistent estimates.
[23] See http://www.energysavingtrust.org.uk/fleet/technology/alternativefuels/

Emission Factors by Passenger Car Market Segments

62. Emission factors for cars by market segment (according to SMMT[24] classifications) were estimated to be consistent with the existing Defra GHG conversion factors by engine size. The market classification split was derived using data between 1997 and 2006 on the average emission factors and the annual proportions of new car sales by market segment from the annual SMMT reports on new car registrations by CO_2 emissions[25]. Consistent with the methodology used to derive the original Defra car engine size based emission factors, the test-cycle based data was uplifted by 15% to take into account 'real-world' impacts. The supplementary market class based emission factors for passenger cars are presented in Table 13.

Table 13: New passenger car market class based CO_2 emission factors

Car Market Segment	Example Model	Average in-use emission factor for segment, gCO_2 per km	
		Petrol	Diesel
A. Mini	Smart Fortwo	162.2	133.5
B. Supermini	VW Polo	176.9	145.5
C. Lower Medium	Ford Focus	201.8	171.2
D. Upper Medium	Toyota Avensis	219.8	191.2
E. Executive	BMW 5-Series	263.2	234.0
F. Luxury	Bentley Continental GT	358.8	318.9
G. Sports	Mercedes SLK	272.0	241.8
H. Duel Purpose 4x4	Land Rover Discovery	304.1	270.3
I. MPV	Renault Espace	243.8	214.8

Taxis

63. New emission factors for taxis were estimated on the basis of an average of the emission factors of medium and large cars from the Defra conversion factors dataset and occupancy of 1.4 (CfIT, 2002[26]). The emission factors for black cabs are based on the large car emission factor (consistent with the VCA[27] dataset based on the NEDC for London Taxis International vehicles) and an average passenger occupancy of 1.5 (average 2.5 people per cab from LTI, 2007[28]).

64. The new emission factors for taxis are presented in Table 14. It should be noted that many black cabs will probably have a significantly different operational cycle to the NEDC, which would likely to increase the emission factor. At the moment there is insufficient information available to take this into account in the current factors.

[24] SMMT is the Society of Motor Manufacturers and Traders that represents the UK auto industry.
[25] Available from SMMT's website at: http://www.smmt.co.uk/publications/publications.cfm?catid=3073&sid=210&tsid=146&curcat=1107
[26] Obtaining the best value for public Subsidy of the bus industry, a report by L.E.K. Consulting LLP for the UK Commission for Integrated Transport, 14 March 2002. Appendix 10.5.1: Methodology for settlements with <25k population. Available at: http://www.cfit.gov.uk/docs/2002/psbi/lek/a1051/index.htm
[27] Vehicle Certification Agency (VCA) car fuel database is available at: http://www.vcacarfueldata.org.uk/
[28] See: http://www.lti.co.uk/news/index.php?p=98

Table 14: New emission factors for average taxis and black cabs

	Average passenger occupancy	gCO_2 per passenger km
Taxi	**1.4**	161.3
Black Cab	**1.5**	175.7

Vans

65. New emission factors for light good vehicles (vans up to 3.5 tonnes), presented in Table 15, were calculated based on revisions to the diesel emission factors used in the National Atmospheric Emissions Inventory (NAEI) proposed to DfT by AEA (2005)[29]. These test cycle based emission factors were then uplifted by 15% to represent 'real-world' emissions, consistent with the approach used for cars agreed with DfT. Emission factors for petrol vehicles were calculated from the relative emissions and vkm of petrol and diesel LGVs in the NAEI. Emission factors for LPG and CNG vans were estimated to be similar to diesel vehicles, as indicated by EST for cars. The average van emission factor was calculated on the basis of the relative NAEI vehicle km for petrol and diesel LGVs for 2005.

Table 15: New emission factors for vans

Van fuel	Van size	gCO_2 per km
Petrol	Up to 1.25 tonne	224.4
Diesel	Up to 3.5 tonne	271.8
LPG or CNG	Up to 3.5 tonne	271.8
Average		**266.1**

Buses

66. Bus emissions per passenger km are influenced by the vehicle model, the driving cycle (proportion of urban, rural and highway driving) and by vehicle average occupancy. The previous emission factor of 89.1 gCO_2/pkm was calculated as an average across all UK buses and coaches. This calculation was based on fleet average gCO_2/km for all bus class and journey data from the UK Greenhouse Gas Inventory and an average load factor of 9.2 calculated using total bus vehicle km and passenger km from Transport Statistics Great Britain (TSGB).

67. Similarly to the situation with rail transport it is desirable to provide more disaggregated emission factors for different types of services, e.g. by local bus and long distance coach services. New emission factors have therefore been developed based on information provided on major bus operator websites/environmental reports (e.g. fuel consumption/emission factors, fuel consumption and passenger km). Emission factors for local buses were calculated based on data from Transport for London (TfL), National Express,

[29] Analysis of Measured Emission Factors for Euro II and Euro III Diesel LGVs and their Incorporation into the National Atmospheric Emissions Inventory. Report by AEA to the Department for Transport, AEAT/ENV/R/2120/Issue 2, December 2005

Go-Ahead, Arriva, Stagecoach and First Group. A total average was estimated based on relative market share according to figures from 'Bus Industry Monitor 2006' available on Stagecoach's website (see Table 16).

Table 16: Market share of local bus services by different operators

Bus operator	Percentage
Transport for London	0.90%
Overseas	11.80%
MUNICIPALS	5.60%
National Express	5.90%
Go-Ahead	9.80%
Management	2.50%
Arriva	14.50%
Independents	14.50%
STAGECOACH	14.00%
First Group	20.60%

Source: Bus Industry Monitor 2006 TAS. Provided on the Stagecoach website at: http://www.stagecoachgroup.com/scg/about/keyfacts/

68. Emission factors for coach services were based on figures from National Express, who provide the majority of scheduled coach services in the UK.

69. The new average emission factors for different bus service types are summarised in Table 17, together with indicative figures from DfT statistics on average bus occupancy levels.

Table 17: New emission factors for buses

Bus type	Average passenger occupancy	gCO_2 per passenger km
Local bus	8.9	115.8
London bus	13.5	81.8
Average bus	***9.7***	***107.3***
Coach	17.1	29.0
Average bus and coach	**12.3**	**68.6**

Notes: Average load factors provided by DfT Statistics Division.

Motorcycles

70. Data from type approval is not currently readily available for motorbikes and CO_2 emission measurements were only mandatory in motorcycle type approval from 2005.

71. Data from the RAC[30] is currently provided in 8 engine size ranges, however this is too diverse a range for the practical purposes of the reporting guidelines and the government 'Act on CO_2 calculator' for personal transport.

[30] RAC data available at: www.rac.co.uk/web/knowhow/owning_a_car/running_costs/motorcycle_services/running_costs

Therefore it was decided in the 2007 update to split the new emission factors into 3 categories:
- Small motorbikes (mopeds/scooters up to 125cc),
- Medium motorbikes (125-500cc), and
- Large motorbikes (over 500cc)

72. New emission factors were developed in 2007 based on reproduced data from the ACEM (European Motorcycle Manufacturers Association) website[31] – sourced from the European Commission's Joint Research Centre. The reproduced graph and table of values are provided in Figure 1 and Table 19.

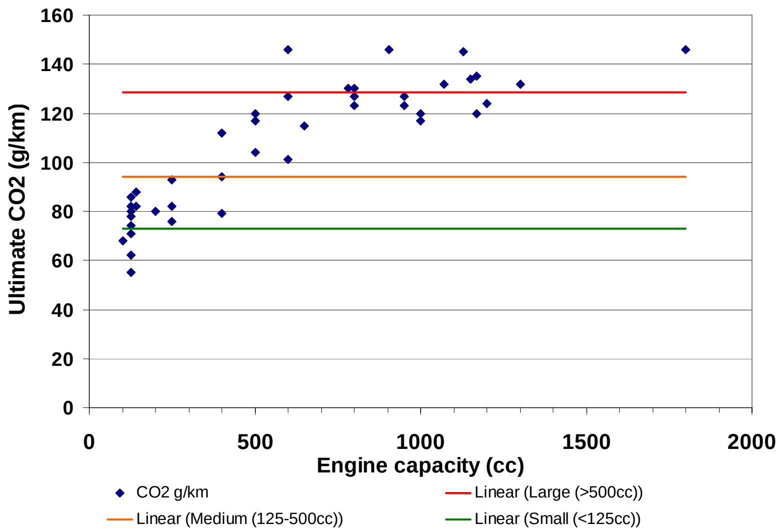
73. The emission factors and categories included in the 2007 update to the Defra conversion factors are summarised in the following Table 18 below. The individual factors have not been updated further in 2008, however the total average has been calculated weighted by the relative number of registrations of each category in 2006 according to DfT statistics from CMS (2007)[32].

Table 18: Revised CO_2 emission factors for motorcycles

Vehicle Type	Engine size	Size label	gCO_2 per km	MPG
Petrol motorcycle	Up to 125cc	Small (mopeds/scooters)	72.9	89.2
	125cc to 500cc	Medium	93.9	69.2
	Over 500cc	Large	128.6	50.6
	Average	**-**	**105.9**	**61.8**

Notes: MPG = miles per gallon. The average is a weighted average based on number of registrations of different size categories.

Figure 1: Chart on CO_2 emissions from motorcycles based on engine capacity (reproduced from ACEM)



[31] Available at: www.acembike.org/motorcycles&society/pressreleases/MS3-Environment-LMercanti.pdf
[32] "Compendium of Motorcycling Statistics: 2007", available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/vehicles/motorcycling/

Table 19: Dataset on CO_2 emissions from motorcycles based on engine capacity (reproduced from ACEM)

Motorbike Size	cc	gCO_2/km	Motorbike Size	cc	gCO_2/km
Small	100	68.0	Large	600	146.0
Small	125	55.0	Large	600	127.0
Small	125	62.0	Large	600	101.0
Small	125	74.0	Large	650	115.0
Small	125	78.0	Large	780	130.0
Small	125	80.0	Large	800	123.0
Small	125	82.0	Large	800	127.0
Small	125	86.0	Large	800	130.0
Small	125	71.0	Large	905	146.0
Average Small		**72.9**	Large	950	127.0
Medium	140	88.0	Large	950	123.0
Medium	140	82.0	Large	1000	117.0
Medium	200	80.0	Large	1000	120.0
Medium	250	93.0	Large	1070	132.0
Medium	250	82.0	Large	1130	145.0
Medium	250	76.0	Large	1150	134.0
Medium	400	79.0	Large	1170	120.0
Medium	400	94.0	Large	1170	135.0
Medium	400	112.0	Large	1200	124.0
Medium	500	117.0	Large	1300	132.0
Medium	500	104.0	Large	1800	146.0
Medium	500	120.0	**Average Large**		**128.6**
Average Medium		**93.9**			

Note: Each data point represents a different motorcycle.

Passenger Rail

74. The approach taken for the 2005 update was criticised for not providing separate emission factors for light rail schemes or the London Underground. Separate factors were included for the 2007 update, which have been updated for 2008 and are provided in Table 21. These are based on the assumptions outlined in the following paragraphs.

International Rail (Eurostar)

75. The international rail factor is based on a straight average of the emission factors for the Eurostar London-Brussels and London-Paris routes. The individual figures are available on the Eurostar website[33], together with information on the basis of the electricity figures used in their calculation[34].

[33] Eurostar emission factors are available on their website at: http://www.eurostar.com/UK/uk/leisure/travel_information/before_you_go/Green_Eurostar.jsp
[34] An outline of the methodology for calculating Eurostar emission factors is available at: http://www.eurostar.com/UK/uk/leisure/about_eurostar/environment/processes.jsp

76. The methodology applied in calculating the Eurostar emission factors currently uses 3 key pieces of information:
   a. Total electricity use by Eurostar trains on the UK and France/Belgium track sections;
   b. Total passenger numbers (and therefore calculated passenger km) on Eurostar London-Paris and London-Brussels services;
   c. Emission factors for electricity (in kgCO_2 per kWh) for the UK and France/Belgium journey sections. These are based on published average data from the UK supplier (British Energy) and the France/Belgium grid averages.

National Rail

77. The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2005/06. The factor is from the DfT Network Modelling Framework (NMF) Environmental Model and has been calculated based on total electricity and diesel consumed by the railways in 2005/06 provided by ATOC, and the total number of passenger kilometres for 2005/06 from DfT rail statistics. The factor for conversion of kWh electricity into CO_2 is based on the 2005 grid mix. This factor is unchanged since the 2007 update.

Light Rail

78. The light rail factors were based on an average of factors for the Tyne and Wear Metro, Docklands Light Rail (DLR) service, the Manchester Metrolink and the Croydon Tramlink.

79. Figures for the DLR and Croydon Tramlink for 2006/07 were taken from Transport for London's 2007 environmental report[35].

80. The factors for Tyne and Wear Metro and the Manchester Metrolink were based on annual electricity consumption and passenger km data provided by the network operators for 2003/4 and a CO_2 emission factor for electricity generation on the national grid from the UK Greenhouse Gas Inventory for 2006 (for consistency with the DLR and Croydon Tramlink figures).

81. The average emission factor was estimated based on the relative line km of the four different rail systems in the absence of total vkm or pkm activity data (see Table 20).

Table 20: CO_2 emission factors and line km for different tram and light rail services

	Type	gCO_2 per pkm	Line km
Tyne & Wear Metro	Light Rail	120.7	59
DLR (Docklands Light Rail)	Light Rail	74.0	27
Croydon Tramlink	Tram	42.0	28
Manchester Metrolink	Tram	42.1	39
Average*		**78.0**	

* Weighted by relative line km

[35] TfL's 2007 environmental report is available at: http://www.tfl.gov.uk/assets/downloads/corporate/TfL-environment-report-2007.pdf

London Underground

82. The London Underground rail factor is from Transport for London's 2007 environmental report (TfL, 2008)[36].

Table 21: Updated 2008 CO_2 emission factors for rail travel

Rail	gCO_2 per passenger km	Source
International rail	17.7	Average figures from Eurostar for London to Brussels and Paris routes
National rail	60.2	DfT Network Modelling Framework (NMF) Environmental ModelCO_2/fuel consumption and DfT rail statistics for 05/06
Light rail (and tram)	78.0	Average of Tyne & Wear Metro, DLR, Croydon Tramlink and Manchester Metrolink
London underground	65.0	Transport for London's 2007 environmental report

RoPax Ferries

83. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA) (BFF, 2007)[37].

84. The BFF study analysed data for mixed passenger and vehicle ferries (RoPax ferries) on UK routes supplied by PSA members. Data provided by the PSA operators included information by operating route on: the route/total distance, total passenger numbers, total car numbers, total freight units, total fuel consumptions.

85. From the information provided by the operators, figures for passenger km, tonne km and carbon dioxide emissions were calculated. Carbon dioxide emissions from ferry fuels were allocated between passengers and freight on the basis of tonnages transported, taking into account freight, vehicles and passengers. Some of the assumptions included in the analysis are presented in the following Table 22.

Table 22: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[38]
Average weight of passenger + luggage, total	0.100	MCA, 2007
Average Freight Unit*, total	22.173	BFF, 2007[39]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[40]

Notes: Freight Unit includes the weight of the vehicle/container as well as the weight of the actual freight load

[36] TfL, 2008. TfL's 2007 environmental report is available at: http://www.tfl.gov.uk/assets/downloads/corporate/TfL-environment-report-2007.pdf
[37] BFF, 2007. "Carbon emissions of mixed passenger and vehicle ferries on UK and domestic routes", Prepared by Best Foot Forward for the Passenger Shipping Association (PSA), November 2007.
[38] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=82A572A99504695B
[39] This is based on a survey of actual freight weights at 6 ferry ports. Where operator-specific freight weights were available these were used instead of the average figure.
[40] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006. Available at: http://www.dft.gov.uk/162259/162469/221412/221522/222944/coll_roadfreightstatistics2005in/rfs05comp.pdf

86. CO_2 emissions are allocated to passengers based on the weight of passengers + luggage + cars relative to the total weight of freight including freight vehicles/containers. For the data supplied by the 11 (out of 17) PSA operators this equated to just under 12% of the total emissions of the ferry operations. The emission factor for passengers was calculated from this figure and the total number of passenger km, and is presented in Table 23.

87. It is important to note that this emission factor is relevant only for ferries carrying passengers and freight and that emissions factors for passenger only ferries are likely to be significantly higher. No suitable dataset has yet been identified to enable the production of a ferry emission factor for passenger-only services (these services were excluded from the BFF, 2007 work for PSA).

Table 23: 2008 CO_2 emission factors for passengers on RoPax ferries

	gCO_2 per passenger km
Large RoPax ferry	115.2

IV. Freight Surface Transport

Heavy Goods Vehicles (HGVs)

88. A revised set of CO_2 conversion factors for road freight has been derived for different sizes of rigid and articulated HGVs with different load factors. The new factors are presented in Table 25 at the end of this section. These replace the factors provided in Table 10 of the 2005 version of the Annex tables to the Defra Guidelines for Company Reporting on Greenhouse Gas Emissions.

89. The factors are based on road freight statistics from the Department for Transport (DfT, 2006)[41], from a survey on the average miles per gallon and average loading factor for different sizes of rigid and artic HGVs in the fleet in 2005, combined with test data from the European ARTEMIS project showing how fuel efficiency, and hence CO_2 emissions, varies with vehicle load.

90. The miles per gallon (MPG) figures in Table 1.9 of DfT (2006) are converted to gCO_2 per km factors using the standard fuel conversion factor for diesel in the Defra GHG conversion factors tables. Table 1.16 of DfT (2006) shows the percent lading factors are on average generally just above or just below 50% in the UK HGV fleet. Figures from the ARTEMIS project show that the effect of load becomes proportionately greater for heavier classes of HGVs. In other words, the relative difference in fuel consumption between running an HGV completely empty or fully laden is greater for a large >33t HGV than it is for a small <7.5t HGV. From analysis of the ARTEMIS data, it was possible

[41] "Transport Statistics Bulletin: Road Freight Statistics 2005", June 2006, SB (06) 27. Available at: http://www.dft.gov.uk/162259/162469/221412/221522/222944/coll_roadfreightstatistics2005in/rfs05comp.pdf

to derive the figures in Table 24 showing the change in CO_2 emissions for a vehicle completely empty (0% load) or fully laden (100% load) on a weight basis compared with the emissions at half-load (50% load). The data show the effect of load is symmetrical and largely independent of the HGVs Euro emission classification and type of drive cycle. So, for example, a >17t rigid HGV emits 18% more CO_2 per kilometre when fully laden and 18% less CO_2 per kilometre when empty relative to emissions at half-load.

Table 24: Change in CO_2 emissions caused by +/- 50% change in load from average loading factor of 50%

	Gross Vehicle Weight (GVW)	**% change in CO_2 emissions**
Rigid	<7.5t	± 8%
	7.5-17t	± 12.5%
	>17 t	± 18%
Articulated	<33t	± 20%
	>33t	± 25%

Source: EU-ARTEMIS project

91. Using these loading factors, the CO_2 factors derived from the DfT survey's miles per gallon data, each corresponding to different average states of HGV loading, were corrected to derive the 50% laden CO_2 factor shown for each class of HGV for the final factors presented in Table 25.

92. The loading factors in Table 24 were then used to derive corresponding CO_2 factors for 0% and 100% loadings in Table 25. Because the effect of vehicle loading on CO_2 emissions is linear with load (according to the ARTEMIS data), then these factors can be linearly interpolated if a more precise figure on vehicle load is known. For example, an HGV running at 75% load would have a CO_2 factor halfway between the values for 50% and 100% laden factors.

93. It might be surprising to see that the CO_2 factor for a >17t rigid HGV is greater than for a >33t articulated HGV. However, these factors merely reflect the miles per gallon figures from the DfT survey that consistently shows worse mpg fuel efficiency, on average, for large rigid HGVs than large articulated HGVs. This might reflect the usage pattern for different types of HGVs where large rigid HGVs may spend more time travelling at lower, more congested urban speeds, operating at lower fuel efficiency than artic HGVs which spend more time travelling under higher speed, free-flowing traffic conditions on motorways where fuel efficiency is closer to optimum. Under the drive cycle conditions more typically experienced by large articulated HGVs, the CO_2 factors for large rigid HGVs may be lower than indicated in Table 25. Thus the factors in Table 25, linked to the DfT miles per gallon survey reflect each HGV class's typical usage pattern on the UK road network.

94. As well as CO_2 factors for 0, 50 and 100% loading, CO_2 factors are shown for the average loading of each weight class of HGV in the UK fleet in 2005.

These should be used as default values if the user does not know the loading factor to use and are based on the actual laden factors and mpg figures from the tables in DfT (2006).

95. UK average factors for all rigid and articulated HGVs are also provided in Table 25 if the user requires aggregate factors for these main classes of HGVs, perhaps because the weight class of the HGV is not known. Again, these factors represent averages for the UK HGV fleet in 2005. These are derived directly from the mpg values for rigid and articulated HGVs in Table 1.9 of DfT (2006).

96. At a more aggregated level still are factors for all HGVs representing the average mpg for all rigid and articulated HGV classes in Table 1.9 of DfT (2006). This factor should be used if the user has no knowledge of or requirement for different classes of HGV and may be suitable for analysis of HGV CO_2 emissions in, for example, inter-modal freight transport comparisons.

97. The conversion factors in Table 25 are in distance units, that is to say, they enable CO_2 emissions to be calculated just from the distance travelled by the HGV in km multiplied by the appropriate conversion factor for the type of HGV and, if known, the extent of loading.

98. For comparison with other freight transport modes (e.g. road vs. rail), the user may require CO_2 factors in tonne km (tkm) units. Table 26 provides such factors for each weight class of rigid and articulated HGV, for all rigids and all artics and aggregated for all HGVs. These are derived from the 2005 fleet average gCO_2 per vehicle km factors in Table 25 and the average tonne freight per vehicle lifted by each HGV weight class. The average tonne freight lifted figures are derived from the tkm and vehicle km (vkm) figures given for each class of HGV in Tables 1.12 and 1.13, respectively, in DfT (2006). Dividing the tkm by the vkm figures gives the average tonnes freight lifted by each HGV class.

99. A tonne km (tkm) is the distance travelled multiplied by the weight of freight carried by the HGV. So, for example, an HGV carrying 5 tonnes freight over 100 km has a tkm value of 500 tkm. The CO_2 emissions are calculated from these factors by multiplying the number of tkm the user has for the distance and weight of the goods being moved by the CO_2 conversion factor in Table 26 for the relevant HGV class.

Table 25: Updated 2008 CO_2 emission factors per vehicle km for HGV road freight

Body Type	Gross Vehicle Weight	% weight laden	gCO_2 per vehicle km
Rigid	<7.5t	0%	525
		50%	571
		100%	617
		41% (UK average)	*563*
Rigid	7.5-17t	0%	672
		50%	768
		100%	864
		39% (UK average)	*747*
Rigid	>17t	0%	778
		50%	949
		100%	1119
		56% (UK average)	*969*
All Rigid	**UK Average**		**895**
Articulated	<33t	0%	672
		50%	840
		100%	1008
		43% (UK average)	*817*
Articulated	>33t	0%	667
		50%	889
		100%	1111
		59% (UK average)	*929*
All Articulated	**UK Average**		**917**
All HGVs	**UK Average**		**906**

Notes: The % weight laden refers to the extent to which the vehicle is loaded to its maximum carrying capacity. So a 0% weight laden means the vehicle is travelling carrying no loads. 100% weight laden means the vehicle is travelling with loads bringing the vehicle to its maximum carrying capacity.

Table 26: Updated 2008 CO_2 emission factors per tonne km for HGV road freight (based on UK average vehicle loads in 2005)

Body Type	Gross Vehicle Weight	gCO_2 per tonne km
Rigid	>3.5-7.5t	591
Rigid	>7.5-17t	336
Rigid	>17t	187
All rigid	**UK average**	**276**
Articulated	>3.5-33t	163
Articulated	>33t	82
All articulated	**UK average**	**86**
ALL HGVs	**UK average**	**132**

Light Goods Vehicles (LGVs)

100. New emission factors for light good vehicles (vans up to 3.5 tonnes), presented in Table 27, were calculated based on the emission factors per vehicle-km in the earlier section on passenger transport and an average load factor of 50% or 0.5 tonnes for petrol vans (up to 1.25 tonne gross weight) and 1 tonne for diesel/LPG/CNG vans (up to 3.5 tonne gross weight).

Table 27: New emission factors freight carried on vans

Van fuel	Van size	gCO_2 per tonne km
Petrol	Up to 1.25 tonne	448.8
Diesel	Up to 3.5 tonne	271.8
LPG or CNG	Up to 3.5 tonne	271.8
Average		**283.3**

Rail Freight

101. In the absence of new information the rail freight emission factor of 21 gCO_2 per tonne km is unchanged since the 2007 update (Table 28).

102. The value for rail freight is provisional and based on currently available information on fuel consumption and CO_2 emissions by diesel freight trains in the UK in 2005 produced by the UK Greenhouse Gas Inventory[42] on the basis of average fuel consumption rates of diesel locomotives and estimated freight train km and DfT statistics on the total tonne km rail freight moved in 2005: Transport Statistics Great Britain (Table 4.1).

103. The factor can be expected to vary with rail traffic route, speed and train weight, but comprehensive, robust and reliable fuel consumption data are not currently available in the public domain. Freight trains are hauled by electric and diesel locomotives, but specific rail freight energy use data are not available nationally and the current factors assume haulage only by diesel locomotives.

104. Traffic-, route- and freight-specific factors are not currently available, but would present a more appropriate means of comparing modes (e.g. for bulk aggregates, intermodal, other types of freight).

105. The rail freight CO_2 factor will be reviewed and updated when data become available relevant to rail freight movement in the UK.

Table 28: 2008 CO_2 emission factors for rail freight

	gCO_2 per tonne km
Rail Freight	21.0

[42] UK Greenhouse Gas Inventory for 2005 (produced for Defra by AEA Energy & Environment), available at: http://www.defra.gov.uk/environment/statistics/globatmos/gagccukem.htm and http://www.airquality.co.uk/archive/reports/cat07/0704261626_ukghgi-90-05_annexes_final.pdf

RoPax Ferry Freight

106. Based on information from the Best Foot Forward (BFF) work for the Passenger Shipping Association (PSA).

107. The BFF study analysed data for mixed passenger and vehicle ferries (RoPax ferries) on UK routes supplied by PSA members. Data provided by the PSA operators included information by operating route on: the route/total distance, total passenger numbers, total car numbers, total freight units, total fuel consumptions.

108. From the information provided by the operators, figures for passenger km, tonne km and carbon dioxide emissions were calculated. Carbon dioxide emissions from ferry fuels were allocated between passengers and freight on the basis of tonnages transported, taking into account freight, vehicles and passengers. Some of the assumptions included in the analysis are presented in the following Table 29.

Table 29: Assumptions used in the calculation of ferry emission factors

Assumption	Weight, tonnes	Source
Average passenger car weight	1.250	MCA, 2007[43]
Average weight of passenger + luggage, total	0.100	MCA, 2007
Average Freight Unit*, total	22.173	BFF, 2007[44]
Average Freight Load (per freight unit)*, tonnes	13.624	RFS 2005, 2006[45]

Notes: Freight Unit includes the weight of the vehicle/container as well as the weight of the actual freight load

109. CO_2 emissions are allocated to freight based on the weight of freight (including freight vehicles/containers) relative to the total weight passengers + luggage + cars. For the data supplied by the 11 (out of 17) PSA operators this equated to just over 88% of the total emissions of the ferry operations. The emission factor for freight was calculated from this figure and the total number of tonne km (excluding the weight of the freight vehicle/container), and is presented in Table 30.

Table 30: 2008 CO_2 emission factors for freight on RoPax ferries

	gCO_2 per tonne km
Large RoPax ferry	384.3

[43] Maritime and Coastguard Agency, Marine Guidance Note MGN 347 (M), available at: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=82A572A99504695B
[44] This is based on a survey of actual freight weights at 6 ferry ports. Where operator-specific freight weights were available these were used instead of the average figure.
[45] Average of tonnes per load to/from UK derived from Table 2.6 of Road Freight Statistics 2005, Department for Transport, 2006. Available at: http://www.dft.gov.uk/162259/162469/221412/221522/222944/coll_roadfreightstatistics2005in/rfs05comp.pdf

Other Marine Freight Transport

110. In the absence of new information, these emission factors are unchanged from previous years.

111. Factors for the other representative ships (apart from RoPax ferries discussed above) are derived from information in the EMEP-CORINAIR Handbook (2003)[46] and a report by Entec (2002)[47]. This included fuel consumption rates for engine power and speed while cruising at sea associated with different vessels. The factors presented in Table 31 refer to gCO_2 per deadweight tonne km.

112. Deadweight tonnage is the weight of the cargo etc which when added to the weight of the ship's structure and equipment, will bring the vessel down to its designated waterline. This implies the factors are based on a fully loaded vessel. Because the ship's engines are propelling the weight of the ship itself, which is a significant proportion of the overall weight of the vessel and its cargo, reducing the cargo load from the deadweight tonnage will not lead to a proportionate reduction in the amount of fuel required to move the vessel a given distance. For example, decreasing the cargo load to half the ship's deadweight will not reduce the ship's fuel consumption by a half.

113. As a consequence, the factors expressed in gCO_2/tonne km freight will be higher than the figures in Table 31 for ships that are only partially loaded (i.e. loaded to less than the vessel's deadweight tonnage). Figures on the typical loading factors for different vessels are not currently available in the public domain. The CO_2 factors will be reviewed and updated when the loading factors become available to provide factors that are more representative of vessel movements from UK ports. Meanwhile, the factors in Table 31 should be regarded as lower limits.

Table 31: CO_2 emission factors for marine freight transport

Shipping	Weight class (deadweight)	gCO_2 per tonne km
Small tanker	844 tonnes	20.0
Large tanker	18,371 tonnes	5.0
Very large tanker	100,000 tonnes	4.0
Small bulk carrier	1,720 tonnes	11.0
Large bulk carrier	14,201 tonnes	7.0
Very large bulk carrier	70,000 tonnes	6.0
Small container vessel	2,500 tonnes	15.0
Large container vessel	20,000 tonnes	13.0

[46] EMEP/CORINAIR (2007), Atmospheric Emission Inventory Guidebook, 5th Edition. Available at: *http://reports.eea.europa.eu/EMEPCORINAIR5/en/page002.html*

[47] Entec (2002), Quantification of emissions from ships associated with ship movements between ports in the European Community", Report for European Commission, DG ENV. Belgium; Main Contributors Chris Whall, Karen Archer, Layla Twigger, Neil Thurston, David Ockwell, Alun McIntyre, Alistair Ritchie (Entec) and David Cooper (IVL).

ANNEX: Extract from the CRG Passenger Transport CO_2 Emission Factor Methodology Paper of July 2007.

AVIATION

Previous Approach

1. The Annexes to the Defra Company Reporting Guidelines (CRG), released in July 2005, report CO_2 emission factors for estimating greenhouse gas emissions.

2. For aviation, there were two factors, one for short haul and one for long haul, as follows:
   - Long haul 110 g/CO_2 per passenger km
   - Short haul 150 g/CO_2 per passenger km

3. The CO_2 emission factors were calculated on the assumptions that for long haul, flight distance was 5000 nautical miles (9260km) on a B747-400 aircraft with 450 seat capacity and 70% load factor (for 2003 from TSGB 2004[48]). For short haul, a distance of 500 nautical miles was assumed (926km) for a B737-400 with 128 seat capacity aircraft and 65% load factor (TSGB 2004).

4. Emissions per passenger km were derived from fuel consumption data for particular aircraft making these flights, taken from the European CORINAIR (Core Inventory of Air Emissions in Europe) manual (2001) for reporting emissions, and based on the methodological recommendations provided in the EMEP/CORINAIR Emissions Inventory Guidebook (EIG)[49]. This dataset provides fuel consumption data for different aircraft by a range of total journey lengths for each of the different stages: LTO, Taxi out, Take off, Climb out, Climb/cruise/descent, Approach landing, Taxi in.

Revised Approach

5. The previous approach has been criticised for being too simplistic and for not taking into account the higher emissions per km from domestic aviation due to the increased influence of the take off and landing cycle on short haul flights.

6. The revised approach uses more up to date information and assumptions that allow a more representative view of the emissions per passenger km for different types of flights.

7. The revised emission factors are set out below in Table 32. In addition to the two types of flight for which the previous guidelines presented emissions factors, a factor for domestic flights is also provided.

[48] Transport Statistics Great Britain 2004
[49] Chapter B851 on aviation. The full guidebook is available at the EEA website: http://reports.eea.europa.eu/EMEPCORINAIR4/en/page002.html

8. Published data have been relied on to produce these estimates. In order to be consistent with earlier versions of the conversion factors, illustrative aircraft types for each type of flight has been used to illustrate the CO_2 emission factor.

Table 32: Emissions factors for domestic and international flights

	gCO_2 per passenger km[50]	Calculation Assumptions	Example Journey
Domestic (B737-400 and Dash 8-Q400)	158.0	• Load factor 65%[51] • Average emissions of two types of aircraft commonly used on domestic flights • Distance 250 nautical miles (463km) in line with CORINAIR published distance category • 78 seats on the Dash-8 Q400 and 139 seats on the B737-400[52]	**London - Scotland**
Short haul international (B737-400)	130.4	• Load factor 65%[53] • Typical illustrative aircraft type used • Distance 599 nautical miles (1108km)[54] interpolated between CORINAIR published distance categories • 139 seats[55]	**UK – Central Europe**
Long haul international (B767-300ER and B747-400)	105.6	• Load factor 79.7%[56] • Average emissions of two types of aircraft commonly used on domestic flights • Distance 3500 nautical miles (6482km) to be in line with CORINAIR published category • 346 seats on the B747-400 and 261 seats on the B767-300ER	**UK – East Coast USA**

Notes:

- These emissions factors are intended to be an aggregate representation of the typical emissions per passenger km from illustrative types of aircraft for the 3 types of air services. Actual emissions will vary significantly according to the type of aircraft in use, the load etc.
- The emission factors do not include additional impacts of Radiative Forcing (i.e. non-CO_2 climate change impacts) and are designed to be used in conjunction with great circle distances. The total climate impacts of aviation due to Radiative Forcing are estimated by IPCC to be up to 2-4 times those of CO_2 alone, however the science of Radiative Forcing is currently uncertain.

9. In terms of the distances that these emission factors should be applied to, the short haul international figure should be applied to journeys up to 2000nm (3700km, the maximum range of a 737-400 according to the EIG 2006[57]) and the long distance factor applied to anything greater than that. Domestic is obviously applied to domestic flights.

[50] EMEP/CORINAIR Emissions Inventory Guidebook (2006) – available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf
[51] Source: Transport Statistics Great Britain, 2006, DfT, table 2.4
[52] Source: derived from CAA data, table 1.11.1 of Airline Statistics, 2005
[53] Assumed here to be the same as for domestic flights. Note that business flights will have a different load factor to this average which reflects all short haul flights
[54] Short haul distance from Table D8, "Aviation and the Environment, Using Economic Instruments", HMT and DfT, March 2003
[55] Source: derived from CAA data, table 1.11.1 of Airline Statistics, 2005
[56] Load factor for all international flights. Source: Transport Statistics Great Britain 2006, table 2.4
[57] EMEP/CORINAIR Emissions Inventory Guidebook (2006) – available at the EEA website at: http://reports.eea.europa.eu/EMEPCORINAIR4/en/B851vs2.4.pdf

10. The emissions factors in Table 32 are based on typical aircraft fuel burn over illustrative trip distances listed in the Emissions Inventory Guidebook (2006). Long haul is based on a flight length of 6482 km, short haul 1108km and domestic 463km. Actual flight distances do however vary significantly, as demonstrated in the following examples in Table 33 and Table 34.

Table 33: Illustrative long haul flight distances

From London to:		
Area	***Airport***	***Distance (km)***
North Africa	Abu Simbel/Sharm El Sheikh, Egypt	3300
Southern Africa	Johannesburg/Pretoria, South Africa	9000
Middle East	Dubai, UAE	5500
North America	New York (JFK), USA	5600
North America	Los Angeles California, USA	8900
South America	Sao Paulo, Brazil	9400
Indian sub-continent	Bombay/Mumbai, India	7200
Far East	Hong Kong	9700
Australasia	Sydney, Australia	17000

Source:
Distances based on International Passenger Survey (Office for National Statistics) calculations using airport geographic information.

Table 34: Illustrative short haul flight distances

From London to:		
Area	***Airport***	***Distance (km)***
Europe	Amsterdam, Netherlands	400
Europe	Prague (Ruzyne), Czech Rep	1000
Europe	Malaga, Spain	1700
Europe	Athens, Greece	1500

Source:
Distances based on International Passenger Survey (Office for National Statistics) calculations using airport geographic information.

11. Emissions impacts in Table 32 have been estimated based on a calculation using the average flight distance (or actual great circle) and should be increased by 9% to take into account indirect routing/delays. This factor comes from the IPCC's report "Aviation and the Global Atmosphere" (1999), section 8.2.2.3[58], which states that 9-10% should be added to take into account non-direct (i.e. not along the straight line between destinations) routes and delays/circling. DfT also use 9% in their work, which is also consistent with the approach take in the UK Greenhouse Gas Inventory.

12. The factors are slightly lower than those in the 2005 Defra CRG Annexes due to a combination of higher load factors (reflecting the latest data from DfT statistics) and more representative aircraft types included in the calculations.

[58] Available at: www.grida.no/climate/ipcc/aviation/121.htm#8223